AN EXAMINATION OF BREAKWATER PERFORMANCE AT BURNS HARBOR, INDIANA

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This discussion compares incident and transferred spectral results for gages located at Burns Harbor, Indiana. Comparisons are made by examining the differences in the incident and transferred harbor energy spectrums. Spectral analysis allows the energy of the total wave record to be broken down into discrete frequency bands. Energy inside and outside the harbors may then be compared and a transfer factor for each discrete frequency can be determined.

Incident and harbor wave data were collected within and offshore of the breakwater at Burns Harbor, Indiana. The purpose of this data collection effort was to determine characteristics of the rubble mound breakwater located there. Wave records were collected hourly using subsurface pressure sensors. The sample rate for these sensors was 1 H_z and the burst length was 2048 seconds.

The analysis utilized the Welch, [1], spectral analysis method with 50% overlapping segments. Since the raw time series were obtained using sub-surface systems, a depth determined high frequency cutoff was applied. The averaged co-and quad-spectra from each analyzed record were used to calculate significant wave height (H_{m0}), peak period (T_p), and mean wave direction at T_p (D_p) and energy spectrums.

The time period 6 January 2003 0700 thru 7 January 2003 0 was selected for detailed analyses. Figure 1, top plot, shows six successive hourly energy spectrums for IN001, located in the open lake. The lake is relatively flat at 0700 with H_{m0} 0.53 m and T_p about 4.3 seconds. Over the next 5 hours the H_{m0} builds to 1.86 m and the T_p moves to 6.6 seconds. The energy at the long period end of the spectrum is very small. Examining simultaneous analysis results from within the harbor provides a description of the breakwater's performance. Figure 1, bottom plot, shows spectrums for the same six hours at the inside gage, IN002. There is almost no energy at 0700 GMT 1/6/03, with H_{m0} 0.05m and T_p 4.5 sec. In subsequent hours, bimodal spectrums develop as more and more energy is transferred through the breakwater, with peaks $>$20 seconds and between 6 and 10 seconds. The magnitudes of these peaks are small when compared to energy for those frequencies outside the harbor.

To provide a more direct comparison of incident and transferred energy, a transfer coefficient (*xfer*) can be calculated by dividing the transferred energy at each frequency by the corresponding outside energy, eqn.1.

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$$xfer = \frac{E_{if}}{E_{of}} \tag{1}$$

where E_{if} is the energy per frequency transferred inside and E_{of} is the incident energy per frequency from outside the breakwater.

If the breakwater is working well, the overall transfer rate should be low. Figure 4, bottom plot, shows that for the initial hours of the storm, the *xfer* is less than .15 for all wave periods $<$10 seconds for IN002. This means less than 15% of the outside energy is making it into the harbor at those frequencies. The long period *xfer* is $<$1.0 which indicates that the outside long period energy ($>$20 seconds) is still more than that on the inside.

After the first six hours of the storm the H_{m0} stays around 2 meters for the next 8 hours and the T_p has shifted from 6 to 8 seconds at IN001 (Figures 2&3, top plots). Little incident energy is evident for wave periods $>$20 seconds. On the inside at IN002, figures 2&3,bottom plots, show that the bimodal spectrums have also grown. Since long period harbor oscillations cause ship movement, the energy for periods $>$20 seconds is of particular interest. There appears to be a relationship between the total energy of the spectrum and energy $>$20 second.

Transfer factors for 1/6/03 1300 to 1/7/03 000 GMT are shown in figures 5&6, bottom plots, for IN002. For some of the periods $>$ 20 seconds, the transfer factor is greater than 1.0. Another observation from these plots is that the transfer factors for waves $<$10 seconds appear to be of the same magnitude throughout the storm.

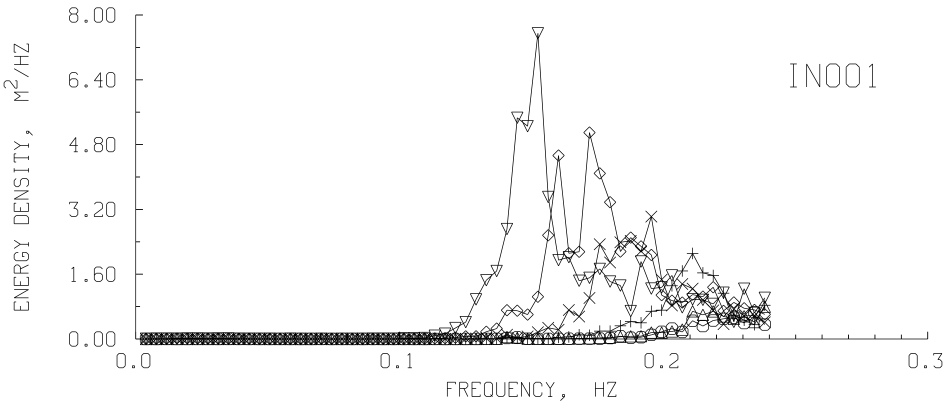
Figure 7 shows the directional wave statistics for January 2003. This plot is an example of the wave climate for IN001 and shows that there were numerous times during the month that the H_{m0} exceeded 0.5 meter. In almost all of these cases, the T_p was greater than 5 seconds. Figure 8, bottom plot, shows the mean transfer rates for each frequency at IN002 for outside wave records with T_p $>$5 seconds. The dashed line represents a one standard deviation band. On average, the breakwater reduces the energy transferred for all frequencies. As expected, the breakwater performs best for short period waves. Figure 9 shows the short period portion of the Figure 8. Mean transfer rates for waves between 5 and 10 seconds is less than 5%.

Portions of the breakwater has undergone repair. Figures 8&9,top plots, illustrate mean transfer rates for a gage placed in front of a repaired section. Energy is, on average, reduced for all frequencies. In particular, energy below 10 seconds is reduced by 50% when compared to results from a gage placed in front of an non-repaired section (Figures 8&9, bottom plots).

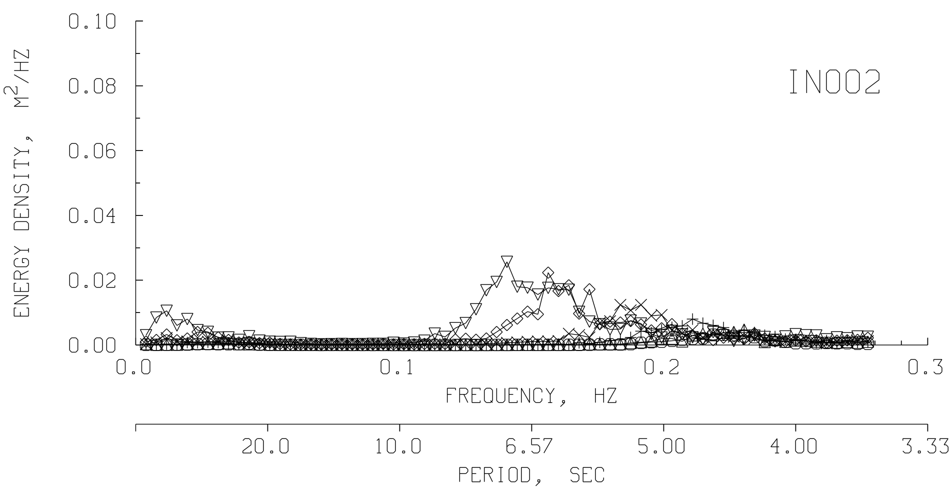
For more information, contact: James P. McKinney or Margaret A. Sabol, CEERD-HC-SO

References

[1] P. D. Welch, “The Use of Fast Fourier Transform for the Estimation of Power Spectrum: A Method Based on Time Averaging Over Short, Modified Periodogams,” *IEEE Transactions on Audio and Electroacoustics*, June 1967.



	H_{mo}, M	T_p, SEC	DEPTH, M
○ = 6-JAN-2003 7:0:0.0	0.53	4.3	12.7
△ = 6-JAN-2003 8:0:0.0	0.59	4.2	12.8
+ = 6-JAN-2003 9:0:0.0	0.96	4.7	12.8
× = 6-JAN-2003 10:0:0.0	1.29	5.1	12.9
◇ = 6-JAN-2003 11:0:0.0	1.71	5.8	12.9
▽ = 6-JAN-2003 12:0:0.0	1.86	6.6	12.9



	H_{mo}, M	T_p, SEC	DEPTH, M
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△ = 6-JAN-2003 8:0:0.0	0.06	4.3	7.7
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× = 6-JAN-2003 10:0:0.0	0.10	5.4	7.9
◇ = 6-JAN-2003 11:0:0.0	0.13	6.4	7.9
▽ = 6-JAN-2003 12:0:0.0	0.15	7.1	7.8

Figure 1: Top Plot: Six successive hourly energy spectrums for the incident gage, IN001, located in the open lake and the harbor gage, IN002, bottom plot.

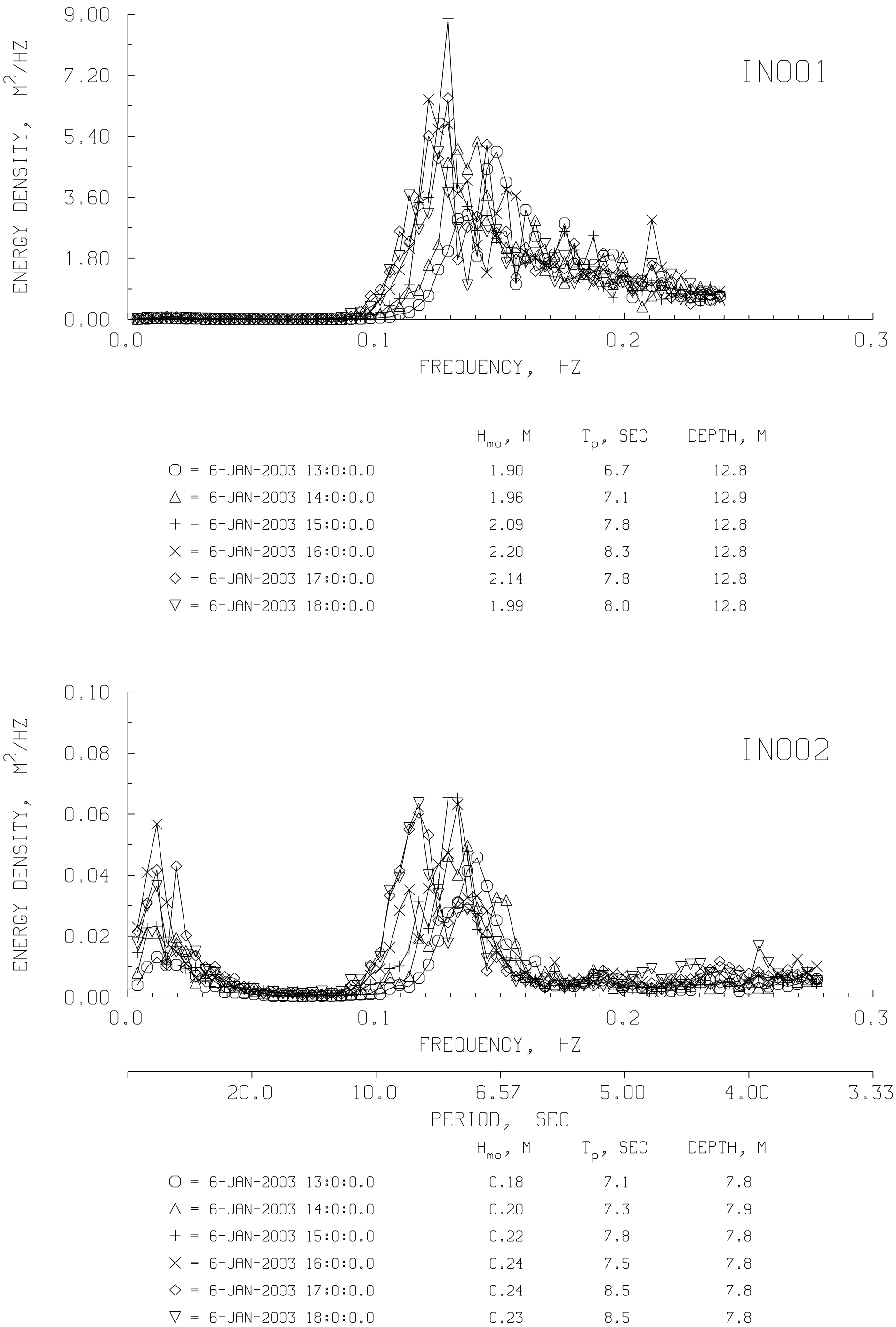

Figure 2: Top Plot: The next six successive hourly energy spectrums for the incident gage, IN001, located in the open lake. Bottom Plot: Corresponding inside spectrum for IN002

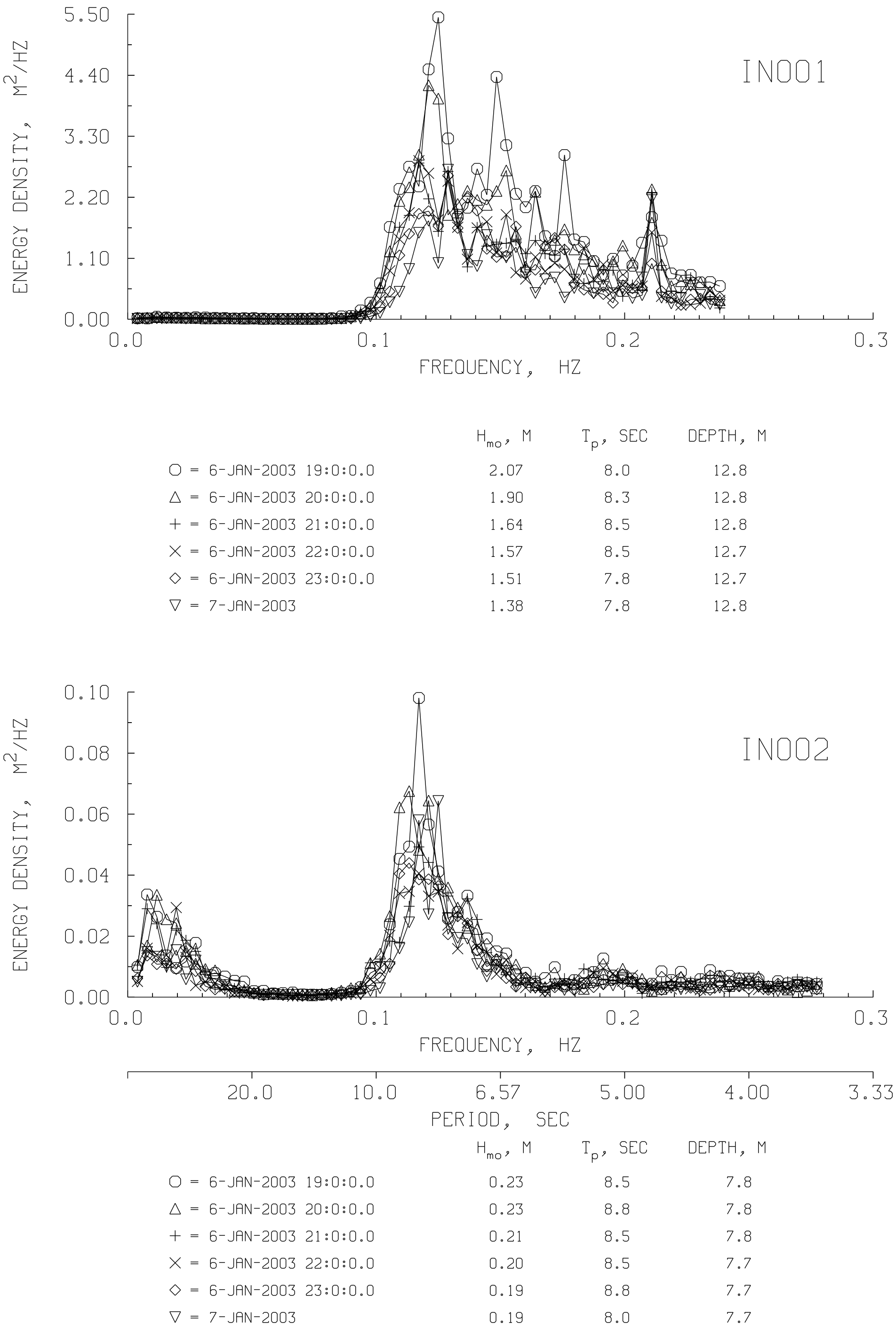

Figure 3: Top Plot: The next six successive hourly energy spectrums for the incident gage, IN001, located in the open lake. Bottom Plot: Corresponding inside spectrums for IN002.

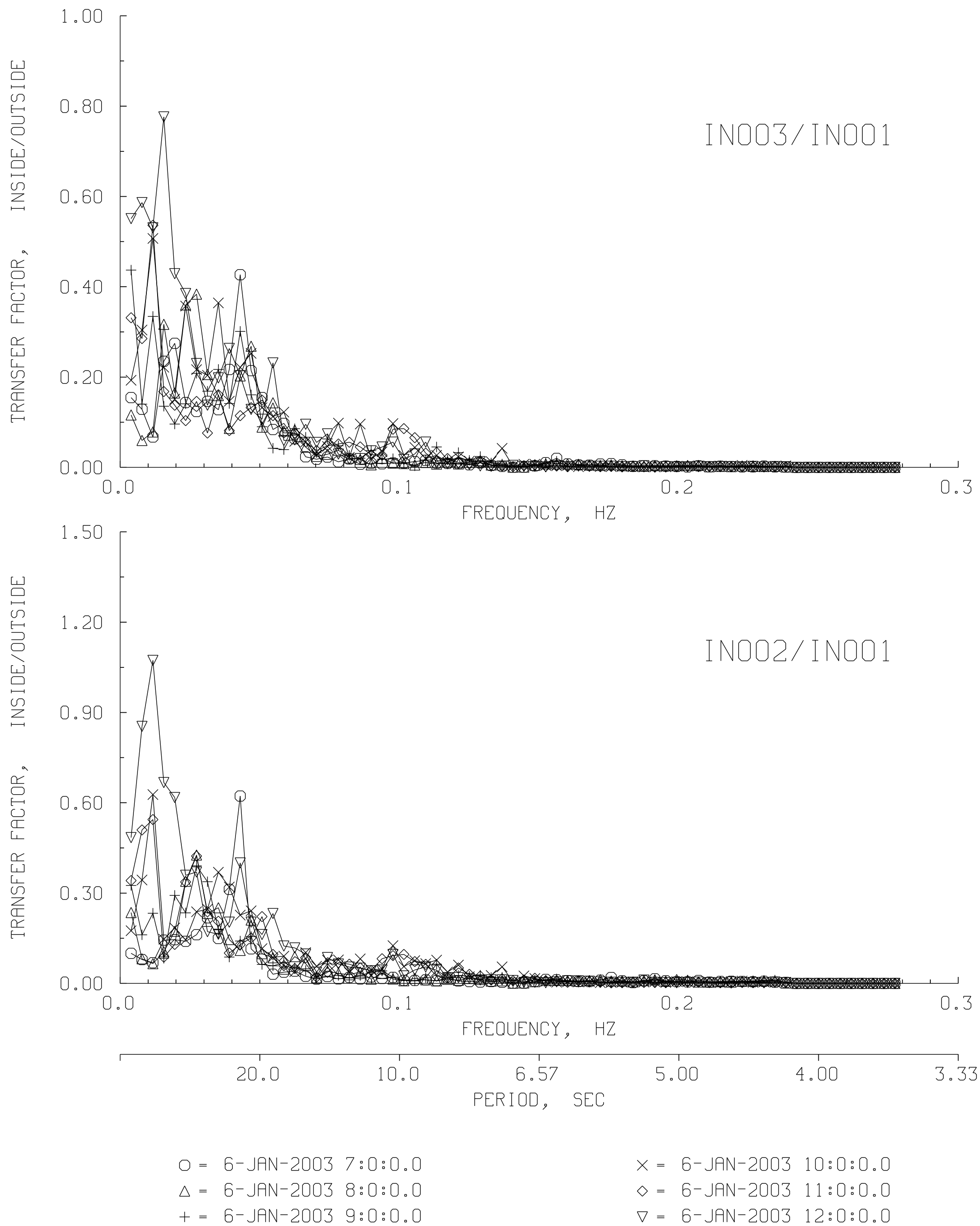

Figure 4: Transfer rates by frequency for the first 6 hours of the storm for gages IN002 and IN003.

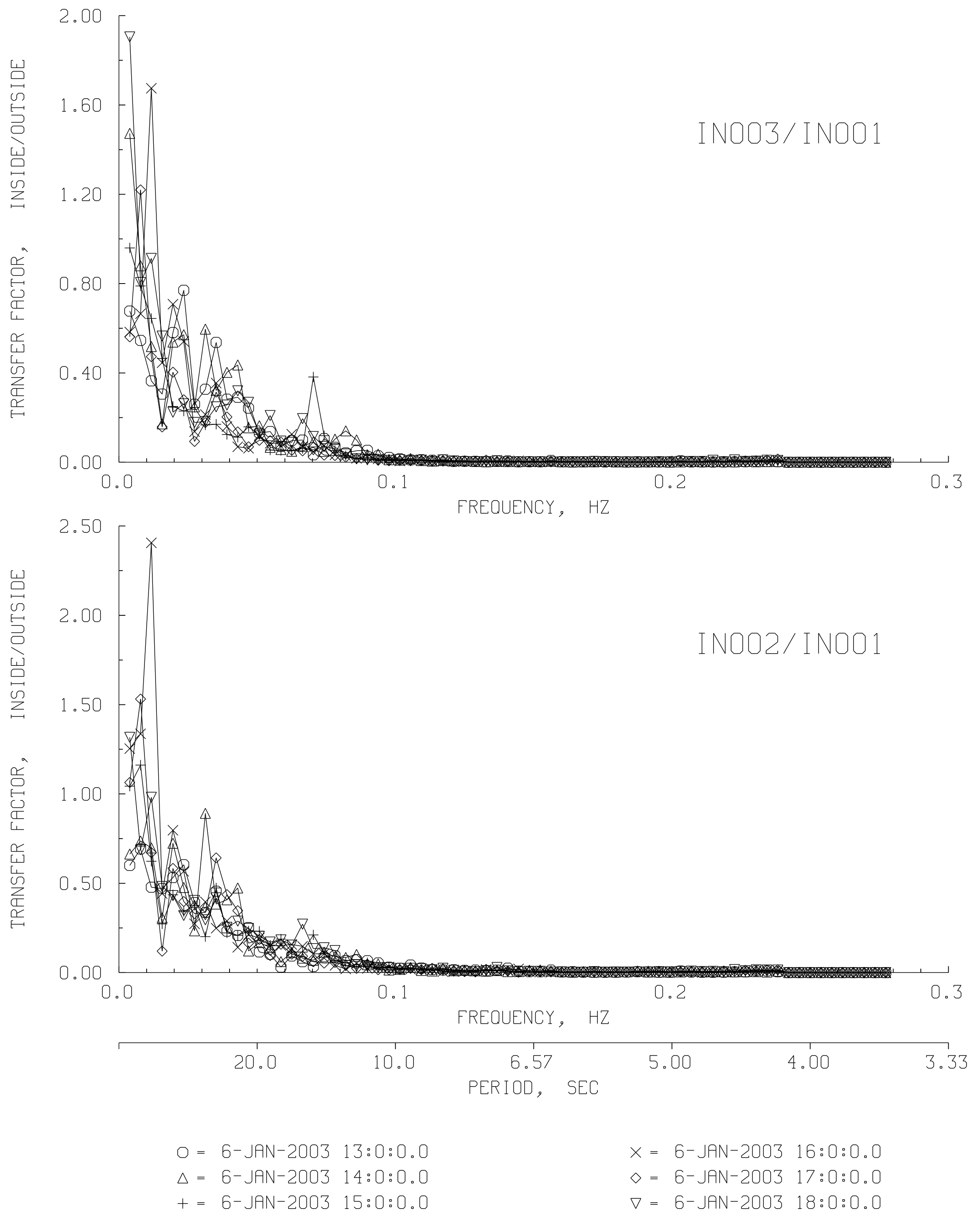

Figure 5: Energy transfer values by frequency for six successive hours for IN002 and IN003.

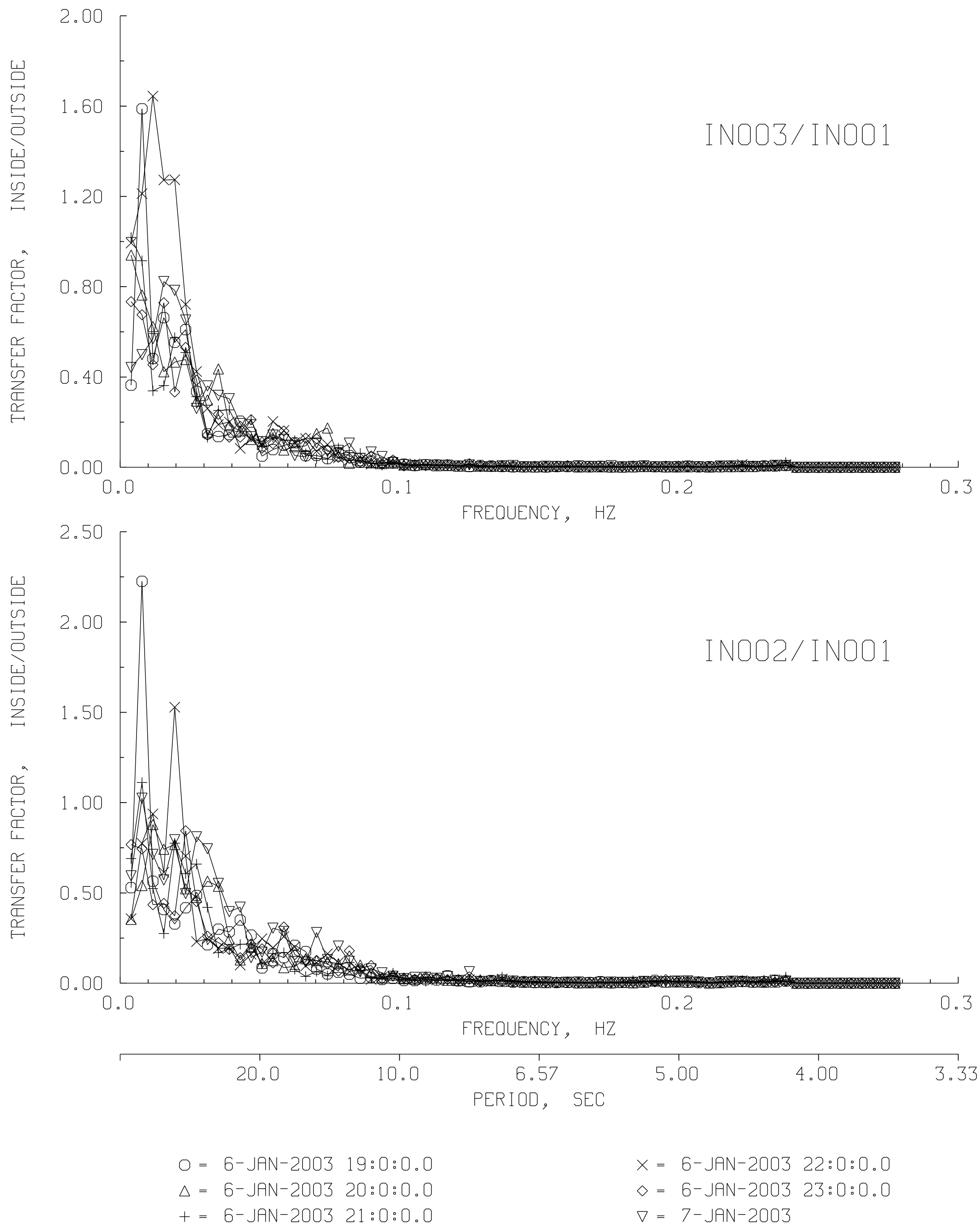

Figure 6: The next six successive hours of energy transfer values by frequency for IN002 and IN003.

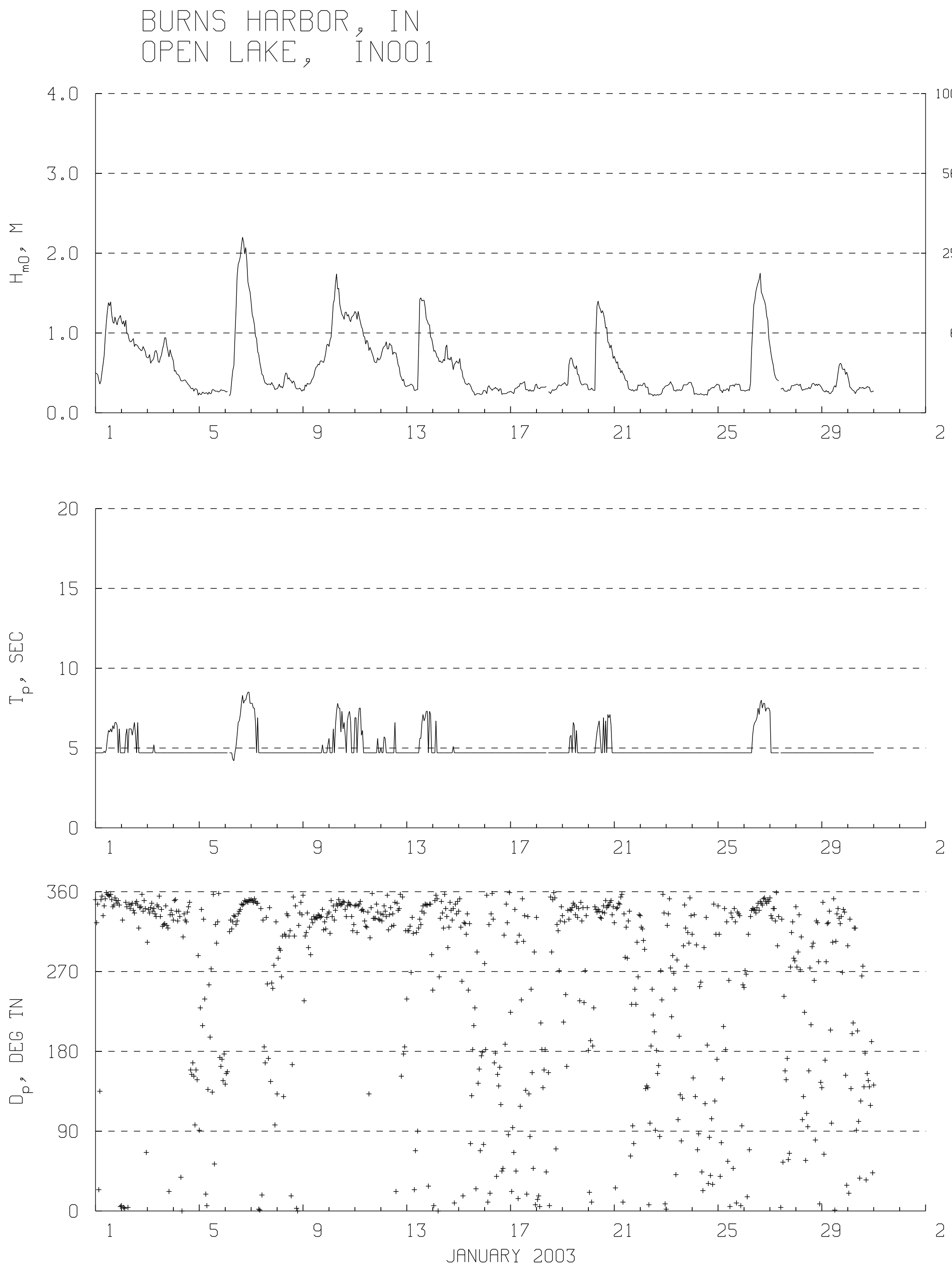

Figure 7: The incident directional wave statistics for January 2003.

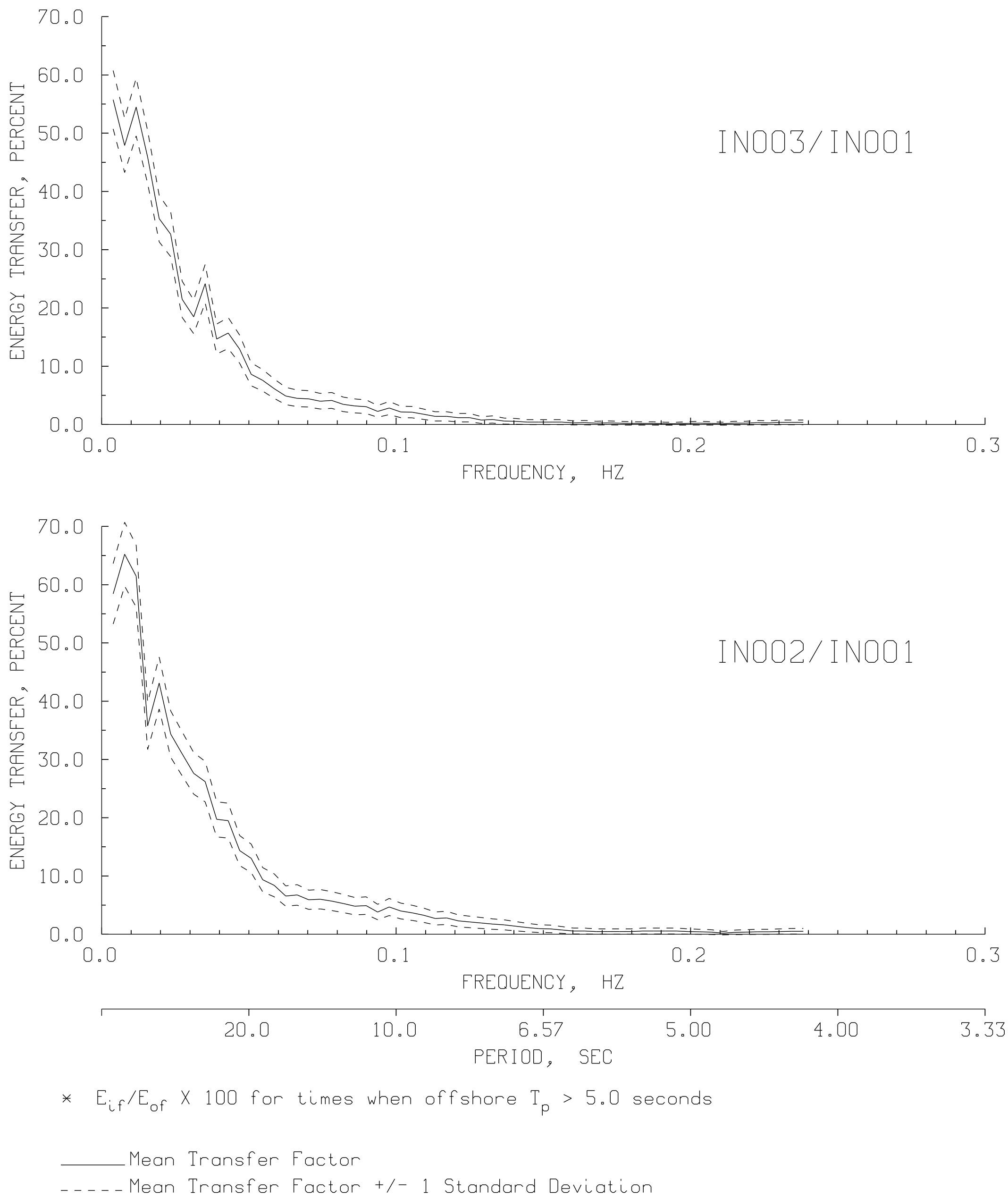

Figure 8: Bottom Plot: The mean transfer rates for each frequency at IN002, for incident wave records with $T_p > 5$ seconds. The dashed line represents a one standard deviation band. Top Plot: The mean transfer rates for IN003.

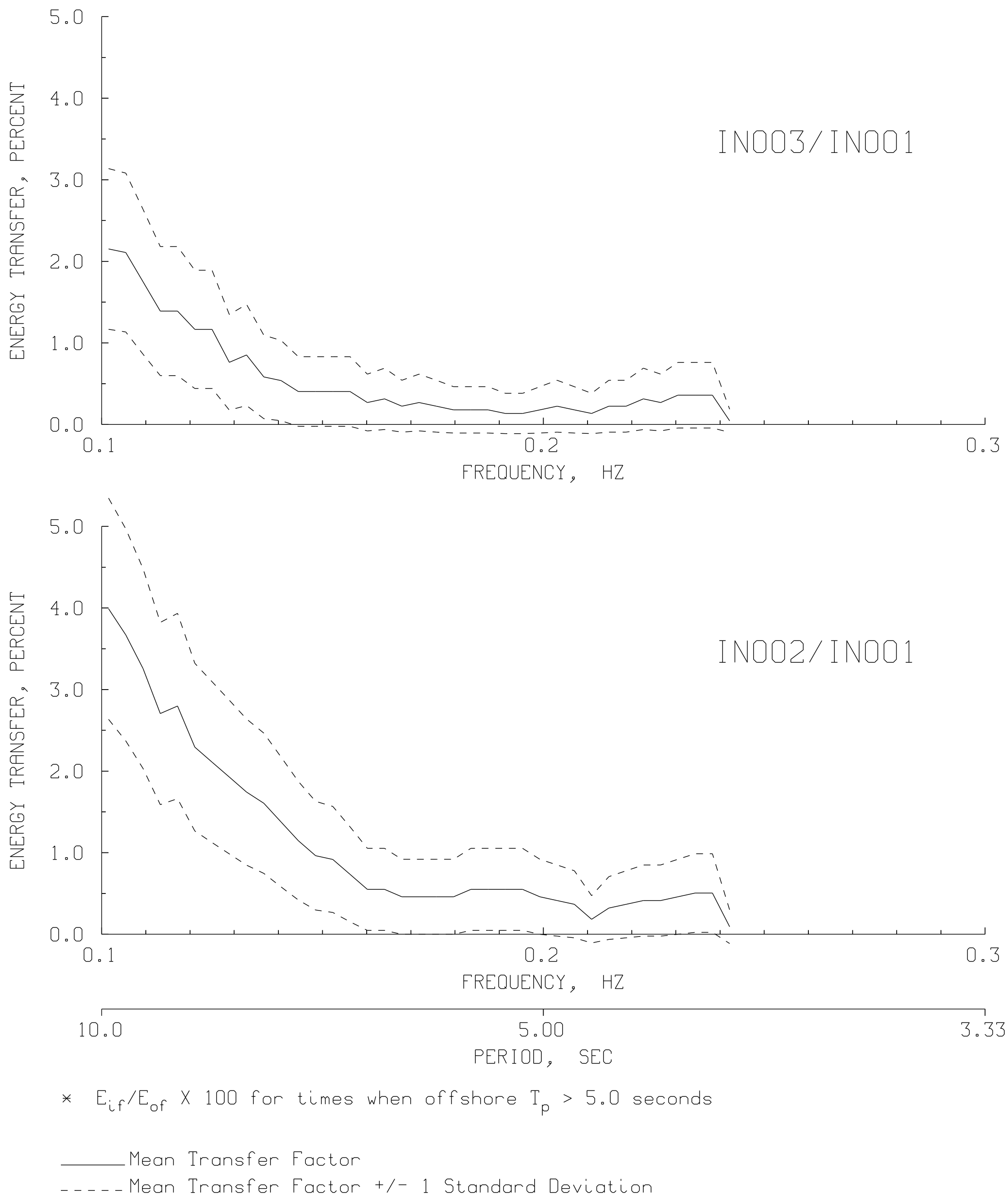

Figure 9: Bottom Plot: The mean transfer rates for each frequency, <10 seconds, at IN002, for incident wave records with T_p >5 seconds. The dashed line represents a one standard deviation band. Top Plot: IN003